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WHEN IRRADIATED BY LASER

by

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Heat Effect Calculations of PC Type HgCdTe Detectors
When Irradiated by Laser

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Abstract

The heat model of laser irradiated PC type HgCdTe detectors is built with the help of measuring the resistance-temperature relation and the time variation when laser irradiated. The laser damage thresholds under three damage mechanisms are calculated.

Key words HgCdTe detector, laser damage

Three possible laser heat damage mechanisms have been proposed by measuring the instantaneous resistance changes of the PC type HgCdTe detector before and after it is irradiated with a 1.06 μ m YAG laser. To study the heat effect, the major concern is to figure out the distribution and time variation of the temperature inside the above-mentioned detector when irradiated by a laser. This paper focuses on building a heat model on the basis of the structure of the detector, determining the related parameters in the model which were attempted corresponding to the experimental results and finally, calculating the power density laser damage thresholds under three heat damage mechanisms.

Relationship between Resistance RD and Temperature of the Detector

The detector used is of the Intrinsic PC type. The relationship curve between the resistance of No. 3 detector RD and temperature T, measured in the experiment, is shown in Fig. 1. Within the range from 77 to 300K, the resistance first increases and then decreases with the rise of temperature, and the maximum value is located at about 115K.

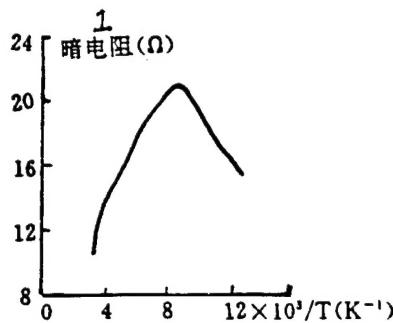


Fig.1 Relationship between resistance RD and temperature T of the detector.

Key: 1. Concealed resistance (Ω)

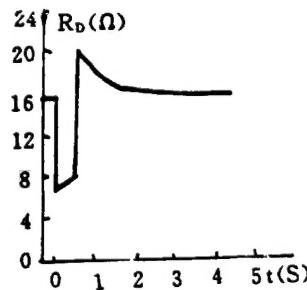


Fig.2 Instantaneous action of resistance of the PC type HgCdTe detector.

Time Variation of RD under Laser Irradiation

RD is supposed to vary with time, due to photoelectric and heat effects, under laser irradiation. As an example, Fig.2

shows the RD variation curve of the No. 3 detector irradiated by a 23 W/cm² 0.5s YAG laser. For the experimental equipment please refer to [1].

The resistance RD drops rapidly, owing to the photoconductive effect, as the laser starts to irradiate when $t=0$, and in the meantime, the detector absorbs laser energy to make the temperature rise in the process. The RD, therefore, will not return right away to the value obtained before the irradiation after the laser stops working; instead, it rises again swiftly to a much higher value (this is because photoconduction caused by the laser disappears immediately when the laser is off) before reaching a phase of relatively slow decrease. Since the RD decreases with the decrease in temperature between 77 and 115K as shown in Fig.1, the slow decrease in the RD after the laser disappearance ($t>0.5$ s), as seen in Fig.2, reflects the heat restoration process of the detector, which, combined with the experimental curve in Fig.1, makes it possible to obtain the time variation curve of the detector temperature when irradiation stops, as demonstrated in Fig.3.

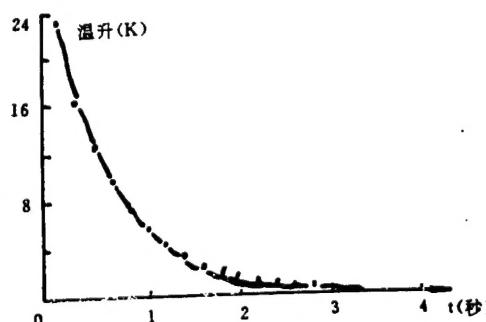


Fig.3 Heat restoration curve (23W/cm², 0.5s).
The solid line represents the experimental value;
the dots stand for the theoretical value calculated.

Heat Model

The structure of the PC type HgCdTe detector is somewhat similar to that of the PV type InSb detector [1]. As with the heat model of the PV type InSb detector [2], the variation in the rising temperature in the HgCdTe(PC) detector can also be calculated before and after laser irradiation. Originally, this is a three-dimensional problem, but it can be solved as a one-dimensional one, because the heat conductivity of the glue layer is very low (about 0.002W/cm.K), while that of HgCdTe and Al_2O_3 is higher than that of the glue layer (about 0.2W/cm.K and 11W/cm.K [3]), and the temperature inside the lamination is about the same. As the exposed format must meet stability requirements and the time pace has to be very small, the concealed format is then used to accelerate the calculation. In addition, the absorption coefficient of HgCdTe is about 10^3 cm^{-1} to 1.06 m , and the rather thin (about $15\text{ }\mu\text{m}$) HgCdTe chips can actually be penetrated by ~20% incident light energy; thus volume absorption should be taken into consideration during calculations. To make it simple, the 20% of penetrated light energy is thought to be absorbed by the first layer of front glue. Figure 3 indicates the comparison between the theoretical and experimental values of the temperature rise in the phase of heat restoration, where the parameters in the calculation model are attempted to fit in with the experimental curve.

Theoretical Calculation of Damage Threshold Value

There might be three damage mechanisms adaptable to the heat damage of the PC type HgCdTe detector used in this paper, as follows:

- (1) Precipitation of Hg. Hg atoms may precipitate from the HgCdTe crystal when the temperature exceeds 80°C , destroying its structure and as a result affecting the performance of the

device;

(2) The lead wire on the HgCdTe crystal, welded with In, may come off when the temperature surpasses 150°C;

(3) The melting of HgCdTe. Its melting point is 720°C.

Among the above three damage mechanisms, the precipitation of Hg is the one that occurs first. The increase of RD (stability value) appearing during the experiment due to long irradiation by a high power density laser suggested that there was definitely precipitation of Hg, because no burn track was found on the surface of the HgCdTe crystal under the microscope. The damage threshold value caused by the lead wire coming off appears to be lower than that caused by the melting of the HgCdTe. Figure 4 shows the relationship between the damage threshold value and the irradiation time under three damage mechanisms. The result of the calculation is found close to that obtained from abroad (damage mechanism 3) [4, 5].

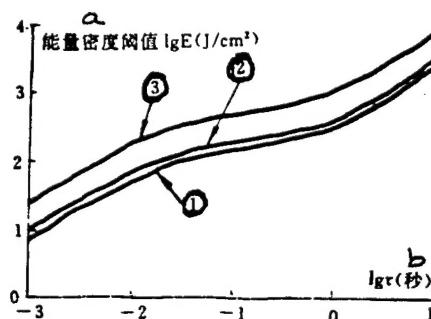


Fig.4 Relationship between the threshold value of the energy density laser damage of the PC type HgCdTe detector and the irradiation time.

Key: a. Threshold value of energy density laser damage $IgE (J/cm^2)$; b. $Igr (s)$

(1), (2) and (3) correspond respectively to the three damage mechanisms given in this paper.

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